Preparing for the Next Generation of Planetary Surface Exploration

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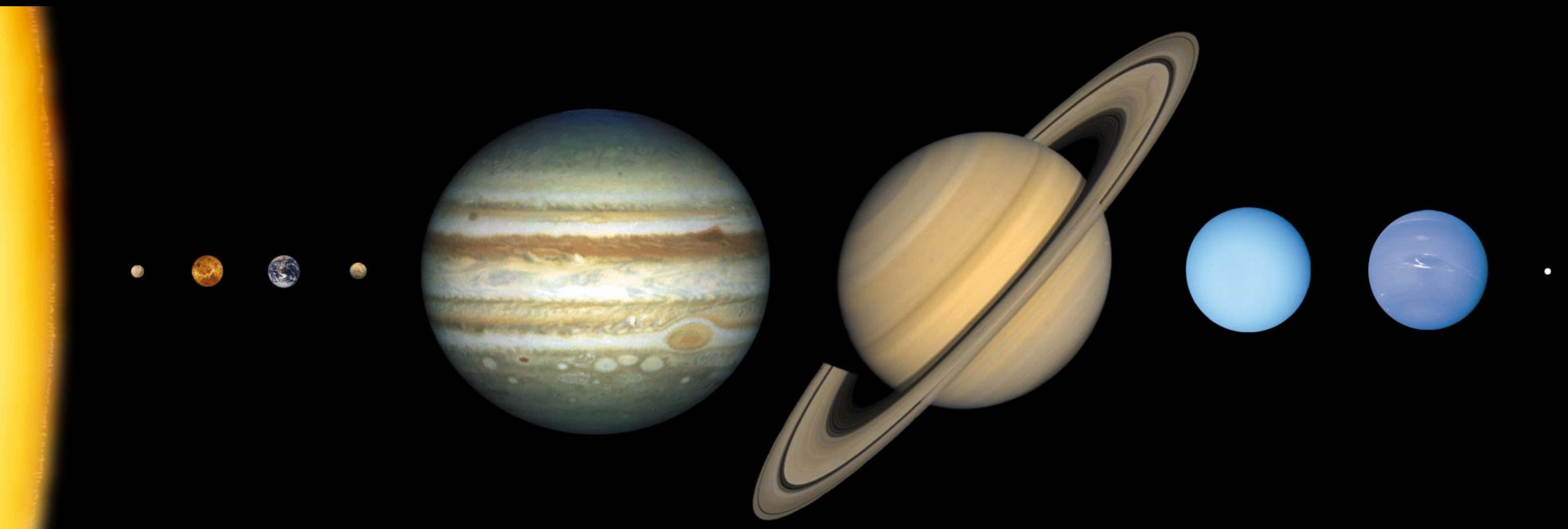
UTEP – Jacobs JETS Contract at NASA Johnson Space Center

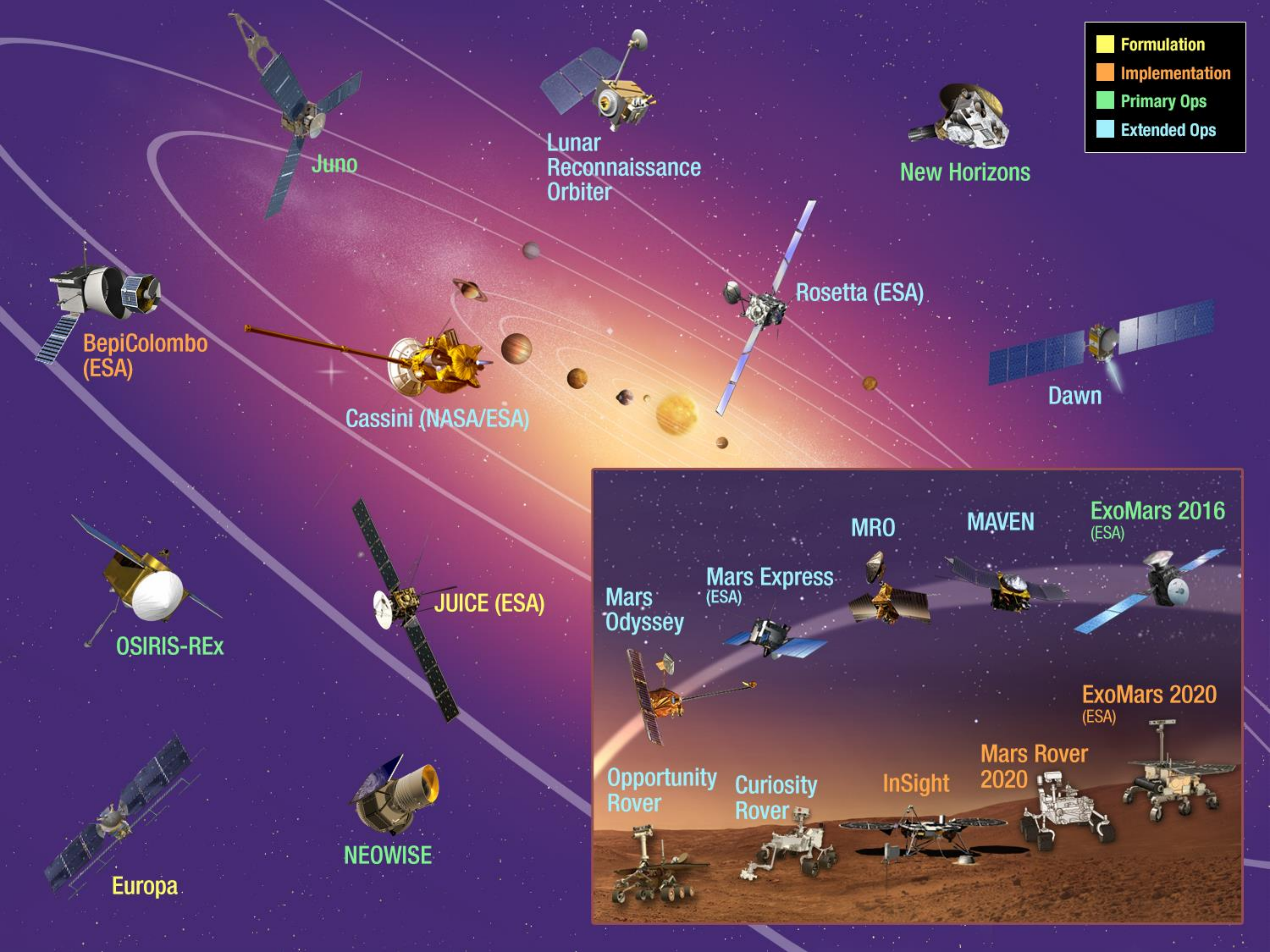
Tuesday, November 8th, 2016

Overview

- Who I am, What I do
- Solar System Exploration: past, current, and future
- Analog Testing
- Field Portable Instruments
- Looking Forward

Solar System Exploration



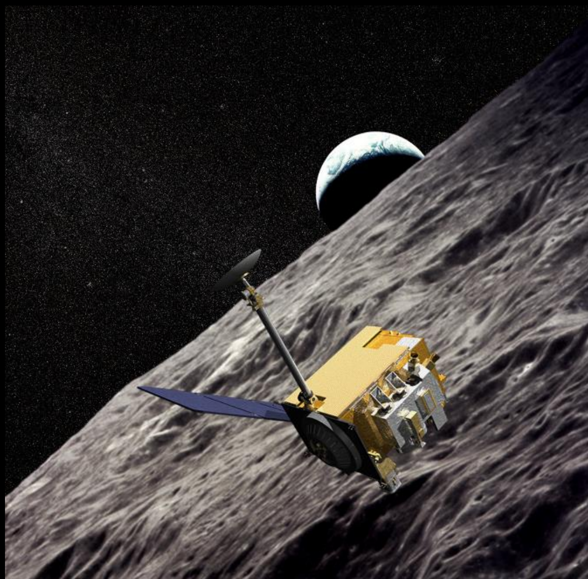


Formulation
Implementation
Primary Ops
Extended Ops
Juno
Lunar Reconnaissance Orbiter
New Horizons
BepiColombo (ESA)
Rosetta (ESA)
Cassini (NASA/ESA)
Dawn
OSIRIS-REx
JUICE (ESA)
Europa
NEOWISE
MRO
MAVEN
ExoMars 2016 (ESA)
Mars Express (ESA)
Mars Odyssey
ExoMars 2020 (ESA)
Mars Rover 2020
Opportunity Rover
Curiosity Rover
InSight

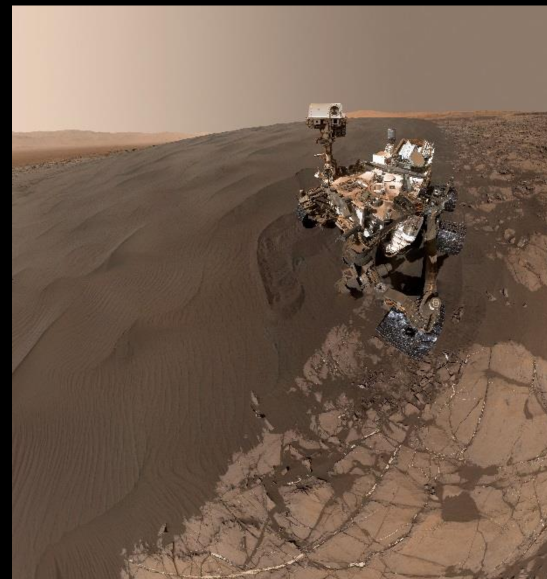
Apollo History of Planetary Surface Exploration

- 6 surface missions from 1969 – 1972
- Sample collection
- Surface science experiments
- Lunar Roving Vehicle

Scientific Drivers for Planetary Exploration



LRO: NASA GSFC Conceptual Images Lab



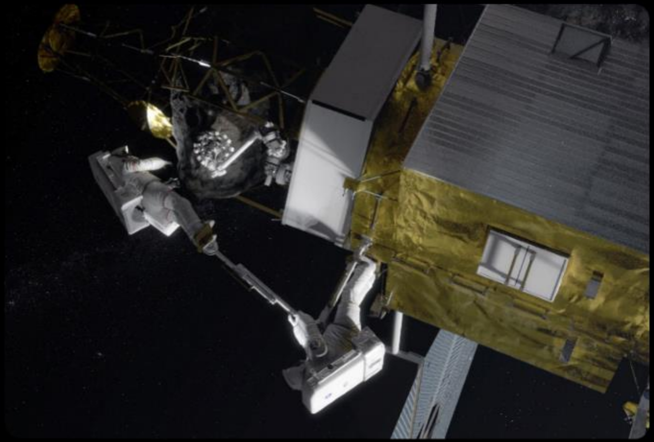
MSL: NASA/JPL-Caltech/MSSS

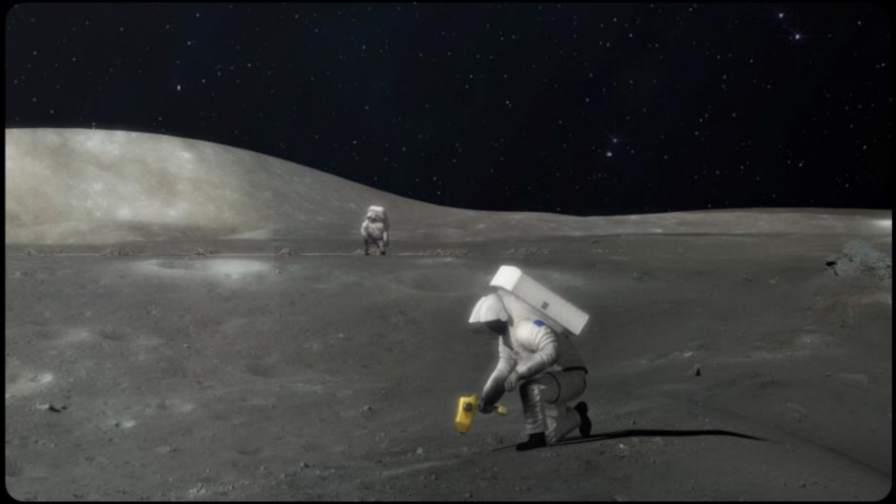
OSIRIS-REX: NASA/Univ. AZ/Lockheed Martin

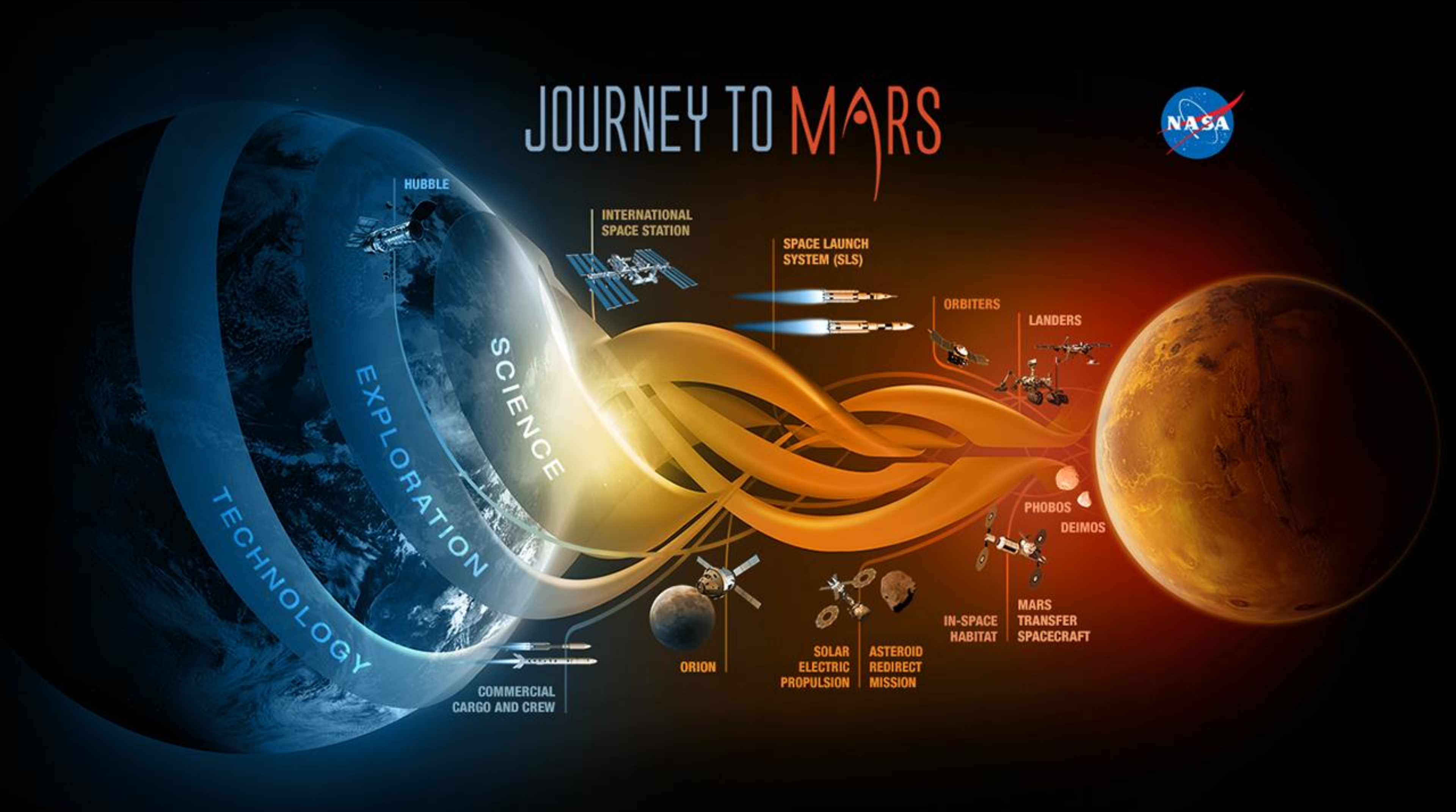
- Massive advancements made since Apollo surface missions, but there are still a number of outstanding science questions across all potential targets of interest for human exploration
- Areas of interest include geology, geophysics, geochemistry, atmospheres, life-related chemistry, etc.
  - Varying levels of human interaction
  - Astrobiology: Planetary Protection

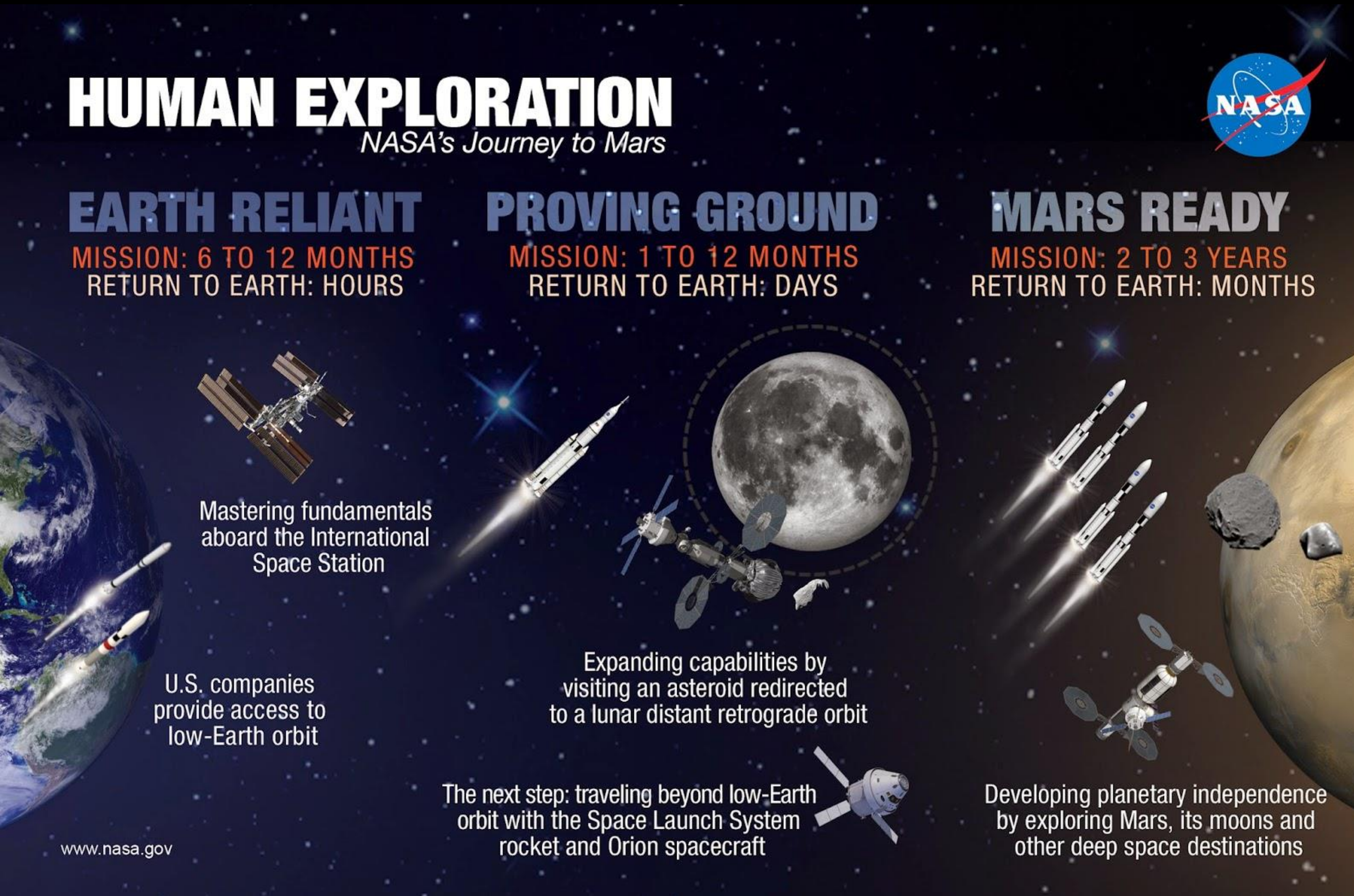
Future Planetary Surface Exploration

- Destinations include small bodies, the Moon, and Mars
- Variable communications delays and atmospheric and gravity conditions
- Flexible technology development is crucial






JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
MARS TRANSFER SPACECRAFT
IN-SPACE HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
ORION
COMMERCIAL CARGO AND CREW


HUMAN EXPLORATION
NASA's Journey to Mars
NASA
EARTH RELIANT
MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS
PROVING GROUND
MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS
MARS READY
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS
Mastering fundamentals aboard the International Space Station
U.S. companies provide access to low-Earth orbit
Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit
The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft
Developing planetary independence by exploring Mars, its moons and other deep space destinations
www.nasa.gov

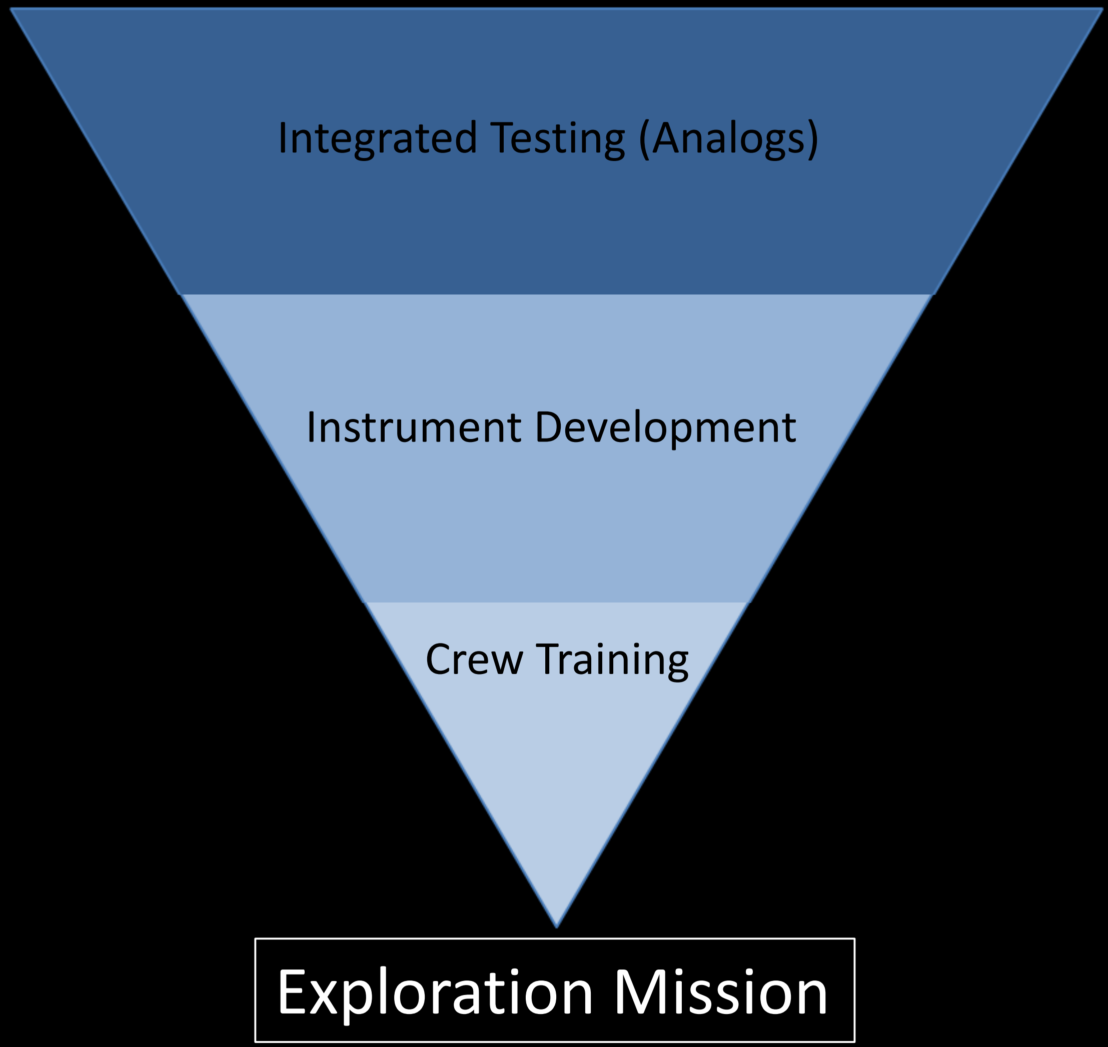
Moving Forward from Apollo

- International Space Station
- Earth Observations
- Science Experiments
- Long Duration Spaceflight

Planetary Surface Exploration

- What do we need to do to get ready to send humans to other destinations
- Test, test, test
- Requires an ongoing, integrated approach

Moving Forward

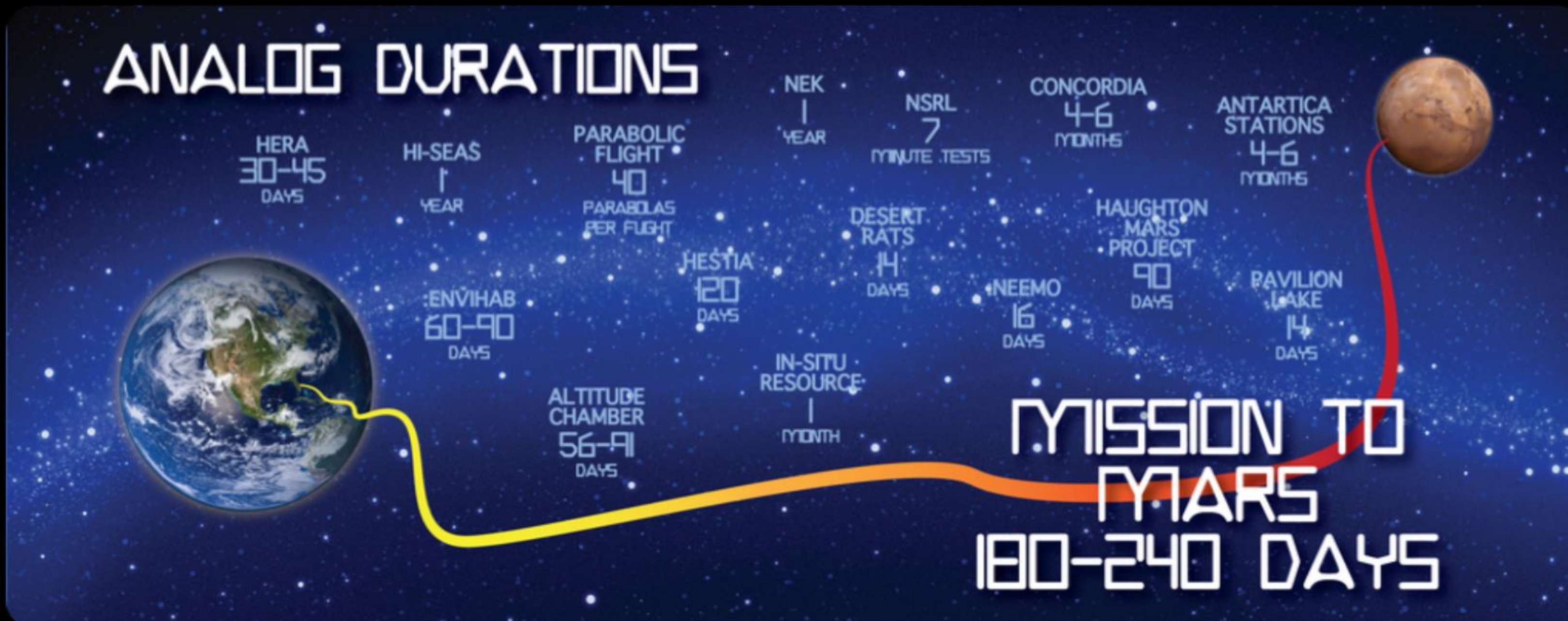


Terrestrial Field Testing

Field testing technology has always been a crucial part of preparing for future exploration

Analog Testing

SCIENCE OPERATIONS TECHNOLOGY



- Multi-disciplinary field test that allows for early end-to-end testing of operational concepts and hardware in a real operational environment
- Evaluates objectives mapped to specific needs and knowledge/technology gaps
- Benefits programs from ISS to Exploration

Desert RATS

- Integrated team of engineers and scientists including most NASA Centers, other Agencies, Military, Academia, High Schools, commercial & international participants
- Tests validate hardware and software as well as mission operations concepts to identify & establish realistic technical requirements applicable to future missions

DRATS - Technology

SCIENCE OPERATIONS TECHNOLOGY

HABITAT ROVER

- Evaluated next generation habitat rover
- Two rovers simultaneously operating with crews of one astronaut and one geologist

SAMPLE COLLECTION

- Apollo-style tools re-evaluated in new exploration paradigm
- Design, test, re-design
- Multi-year tool evolution between geologists and engineers

HABITAT LABORATORY

- Designed for long duration surface stays
- Real-time, in situ analysis allows for sample high-grading

DRATS - Operations

SCIENCE OPERATIONS TECHNOLOGY

Integrated EVA Science Operations

- Examined con ops that enable interaction between the MCC & the crew over varying comm latencies including:
  - Interaction with an integrated Science Team
  - Authentic scientific objectives and hypothesis
  - Flexecution methodology

Sample Collection and Curation Procedures

- Assessed varying procedures for scientific data collection
- Investigated what and how much data must be collected during EVA

Crew Training

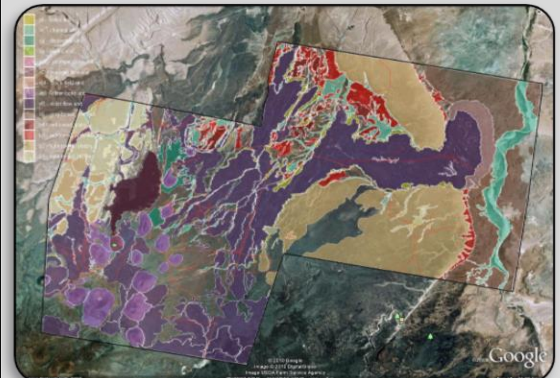
- Follow-up from initial Astronaut Candidate training
- Best practices for training analog crews
- Relationships between astronaut and geologist crewmembers

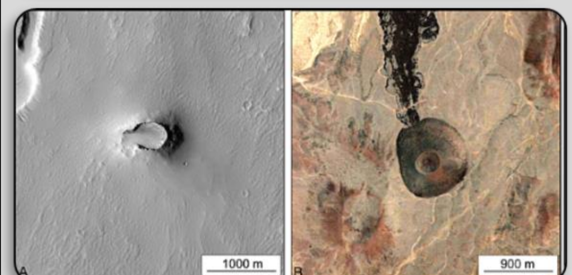
WITH VARYING COMMUNICATION LATENCY CON OPS

DRATS - Science

SCIENCE OPERATIONS TECHNOLOGY

San Francisco Volcanic Field, Arizona



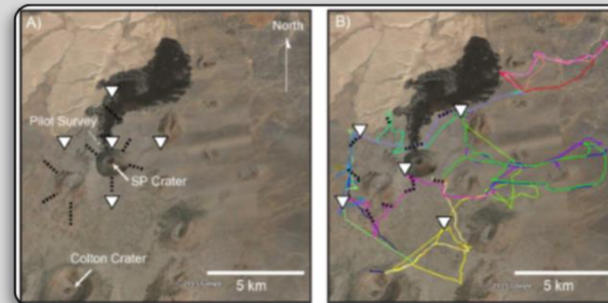


- Analog site north of Flagstaff, AZ
- Mapped by NASA/USGS team with remote sensing data
- Traverse plans developed for each mission

Real-time Sample Collection and Geologic Mapping

- Multiple EVAs designed to map volcanic field
- Samples collected and curated for “return to Earth”
- Initial sample analysis performed in habitat laboratory

Follow-up Science



- New projects funded based on results from DRATS
- Seismic studies of volcanic terrain
- Geochemical studies to map flows and cones

NEEMO

SCIENCE OPERATIONS TECHNOLOGY

- Successful 16 day mission living and working from Aquarius Reef Base
- Completed a combination of Exploration EVA and ISS/Orion related objectives
- International crew with partial crew rotation mid-mission
- Numerous participating organizations across NASA, JSC, ESA, DoD, Research Institutions, Universities, and Industry Partners

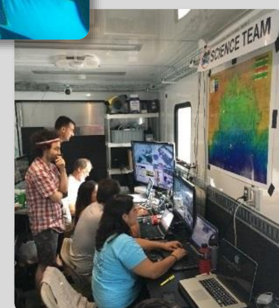
NEEMO - Science

SCIENCE OPERATIONS TECHNOLOGY

NURSERY CONSTRUCTION & SCIENCE

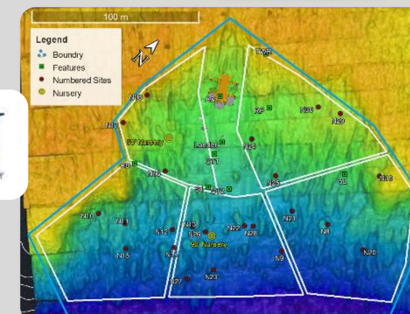
- Constructed and conducted initial science investigation on two long-term coral nurseries near ARB
  - 50’ nursery
  - 90’ nursery (deepest in the world)
- Constructed 5 tree-structures at each site; emplaced 600 samples for scientific research

REEF FOLLOW-UP SCIENCE



- Continued research and sampling conducted during NEEMO 20
- Science team developed the overall sampling strategy and traverse plans

REEF EXPLORATION SCIENCE



- Explored and expanded into new sites and new coral species
- Described, documented, and sampled over 80 additional samples

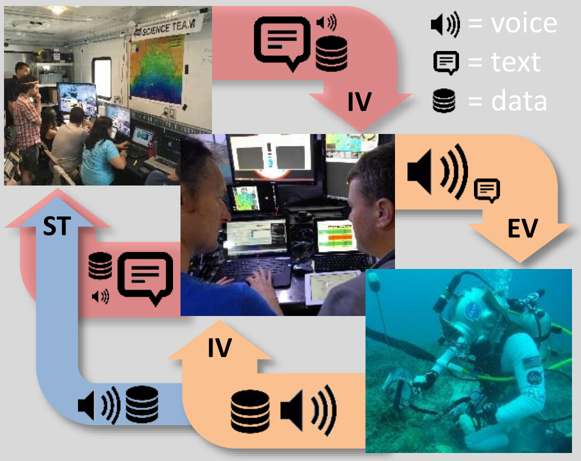
Authentic science now fully integrated into NEEMO EVA operations

Successfully completed all science objectives during 60+ hours of science driven EVA operations

NEEMO - Operations

SCIENCE OPERATIONS TECHNOLOGY

INTEGRATED EVA SCIENCE OPERATIONS



➢ Examined con ops that enable interaction between the MCC & the crew over a long comm latency including:
- Interaction with an integrated Science Team
- Authentic scientific objectives and hypothesis
- Flexecution methodology

NAVIGATION, MAP, & TRAVERSE PLANNING

➢ Assessed tool needs for navigation

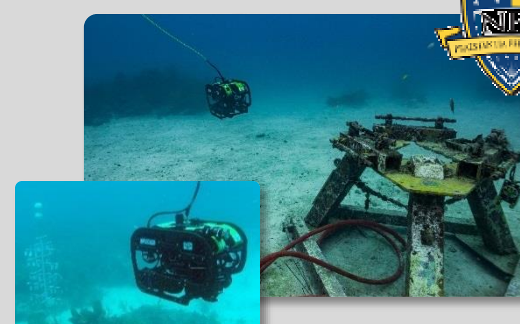
➢ Traverse plan and map on cue cards showed crew regions and paths, and tasks to complete

➢ Utilized Doppler relative nav system for crew to find ROI/zones

OPTICAL COMMUNICATIONS

➢ Successfully deployed, tested, and evaluated a prototype optical communications system

JOINT ROBOTIC-EVA OPERATIONS



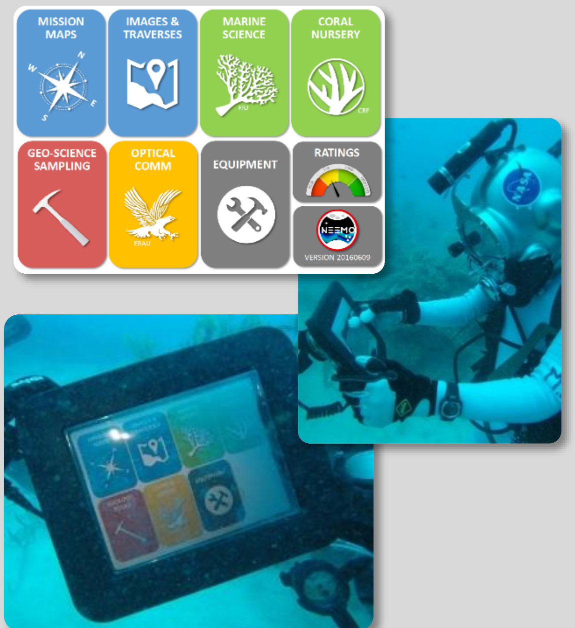
➢ Utilized an ROV as a robotic asset for IV and ST situational awareness of the EVA

WITH LONG (15 MIN) COMMUNICATION LATENCY CON OPS

NEEMO - Technology

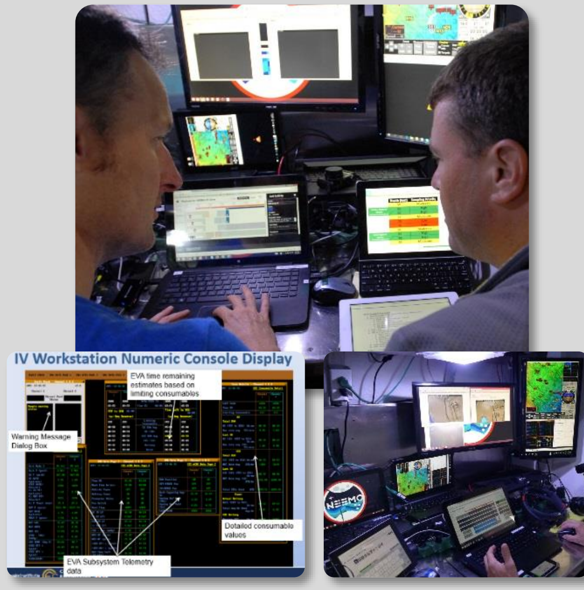
SCIENCE OPERATIONS TECHNOLOGY

DIGITAL CUE CARDS



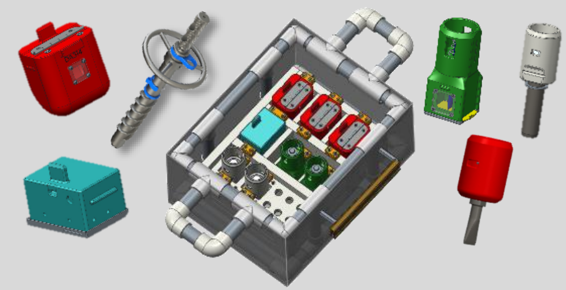
- ➢ Evaluated digital cue cards for EVA crew that allowed crew to operate more effectively and offload IV tasks
- ➢ Potential "one-device" for cue cards/procedures, images/video, instrument control, etc.

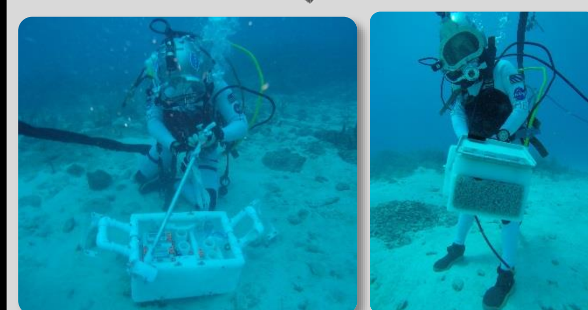
IV SUPPORT SYSTEM



- ➢ Evaluated tools the IV crew needs to handle the large amount of real-time EVA information
- ➢ Evaluated effective setup in constrained location
- ➢ Multiple displays of camera feeds, timeline, nav/comm/sub systems, procedures, logs, etc.

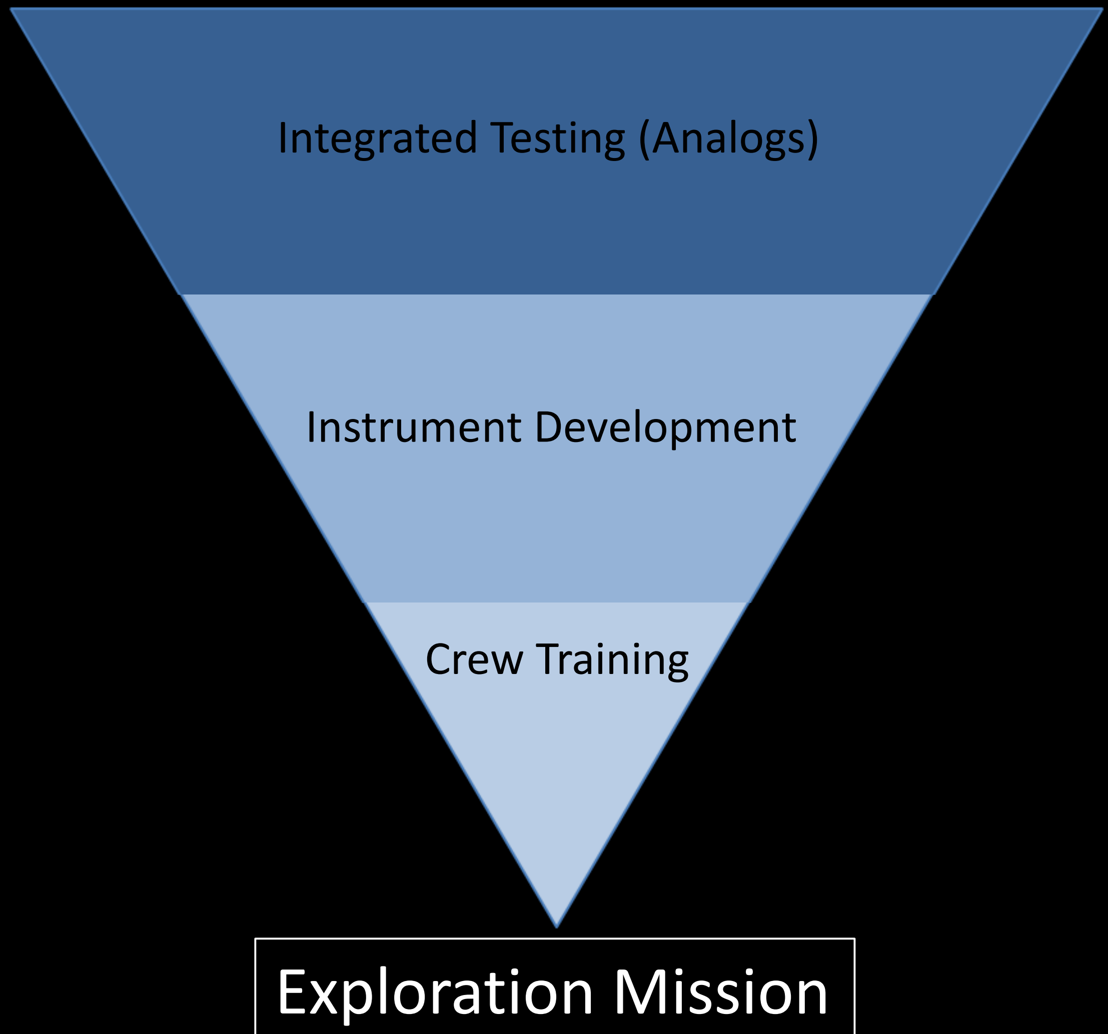
SCIENCE SAMPLING TOOLS & GEOLOGY SAMPLING KIT





- ➢ Evaluated EVA tools and hardware for science sampling
- ➢ Sample Briefcase housed various end effectors with two different drivers (manual and powered)

Portable Instruments



Field Portable Instrumentation

- Goal of any instrument is to maximize science return and increase efficiency of real-time surface operations

- Influences not only sample collection, but also in situ data analysis to inform traverse activities

Field Portable Instrumentation

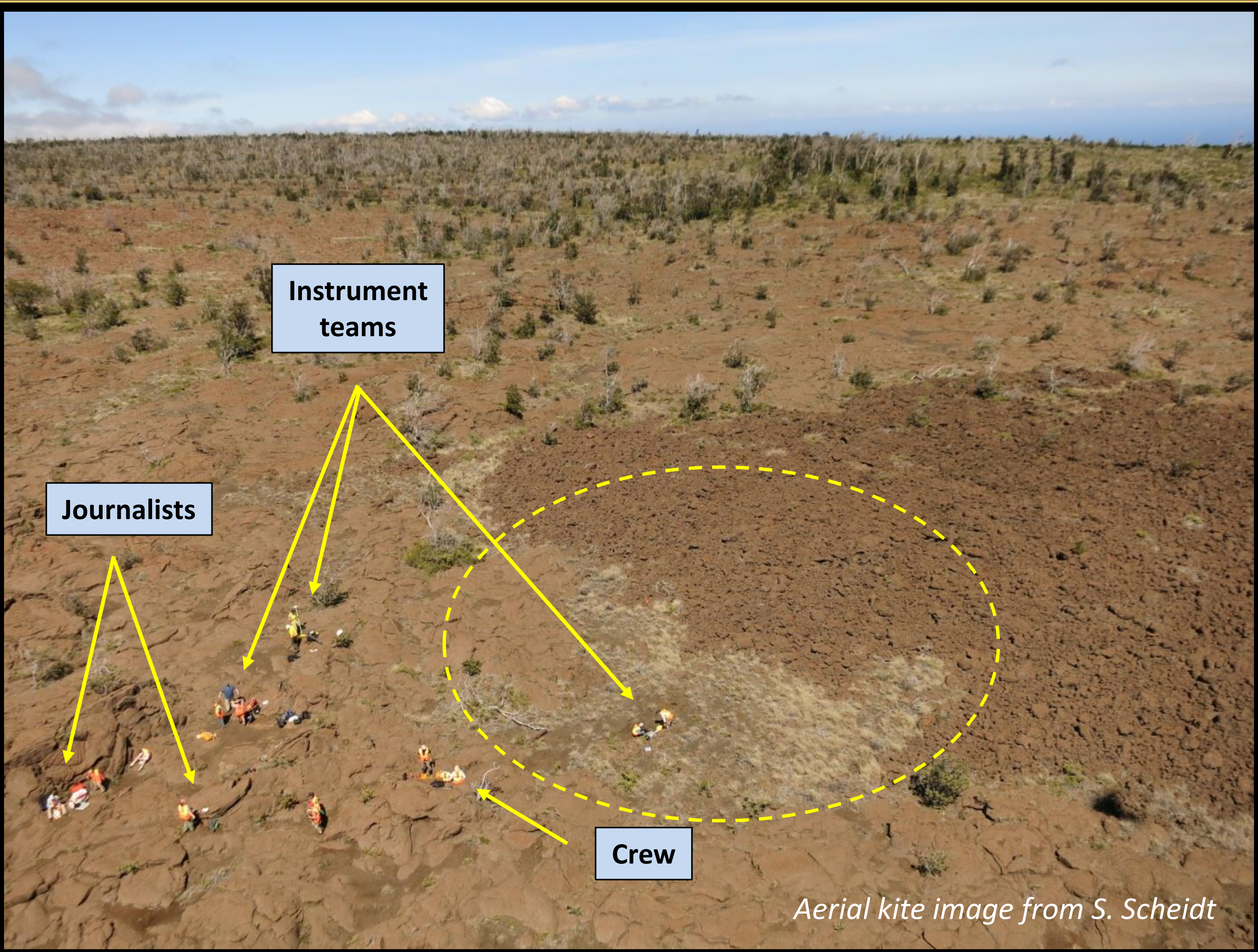
REMOTE IN SITU AND SYNCHROTRON STUDIES FOR SCIENCE AND EXPLORATION

Solar System Exploration Research Virtual Institute

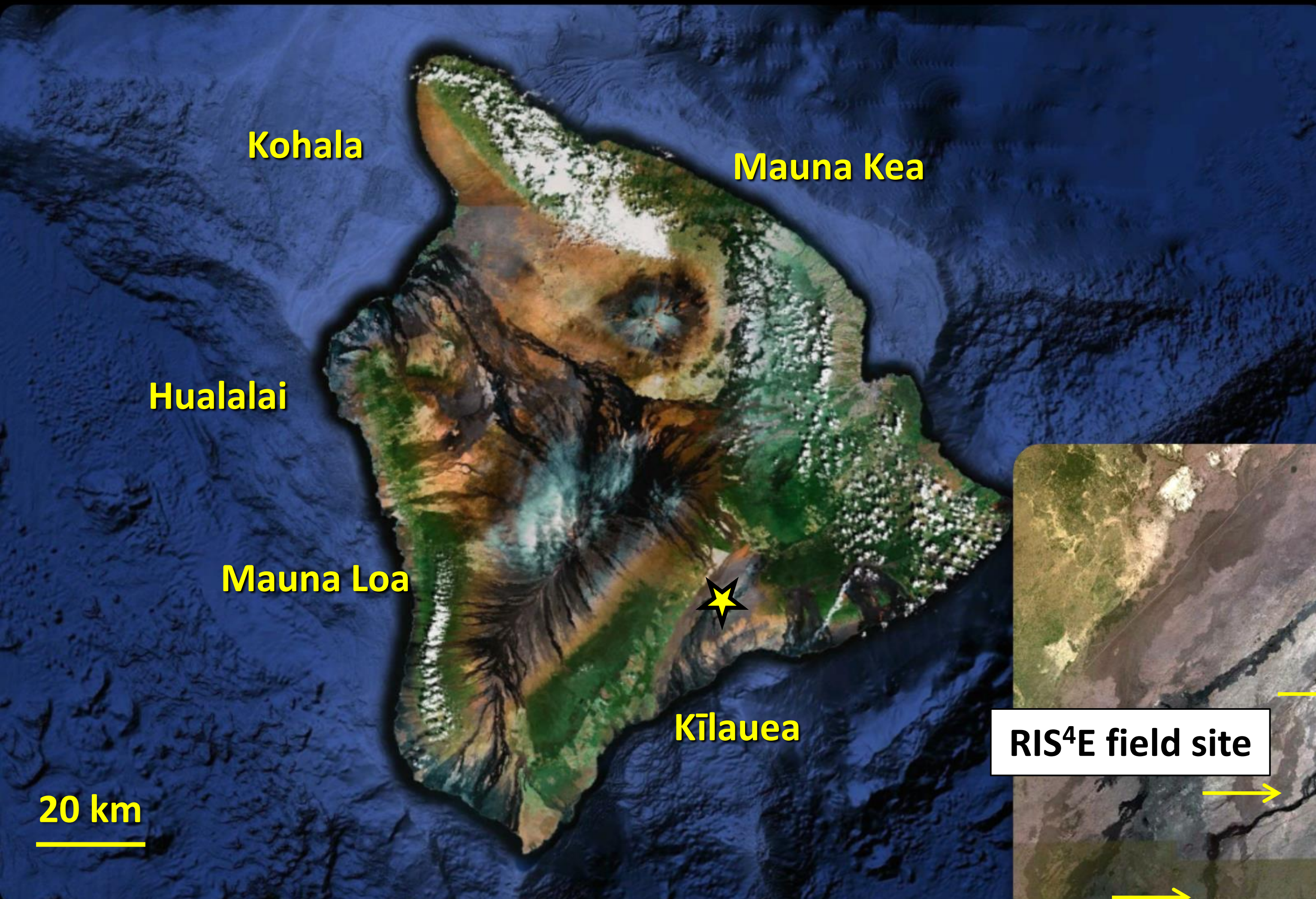
RIS^{4}E Field Methods

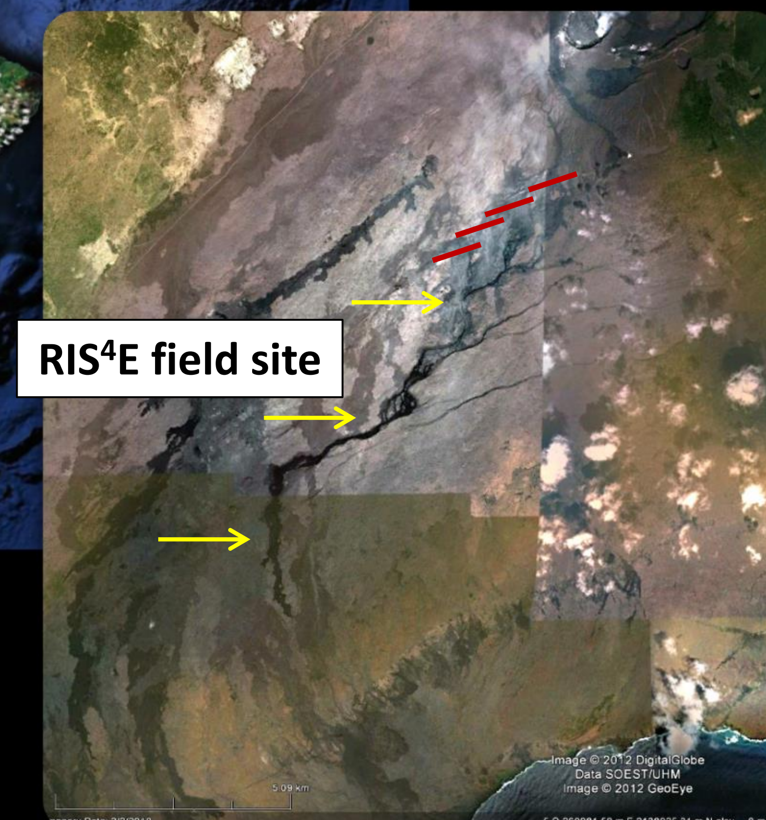
- New science
- Evaluate role of portable instruments for *in situ* analysis
- Recommendations for instrument operations and technology development

RIS4E Field Operations



RIS^{4}E FIELD SITE: Kīlauea December 1974 Flow





Designed to study physical volcanology & characterize chemistry & mineralogy of lava and alteration products

The D1974 Flow as an Analog

- Desert environment with brief damp periods
- Alteration resulting from plume-flow interaction
- Basaltic flows interspersed with basaltic ash and basaltic sediments
- Low-slope flow morphology

RIS^{4}E Field Instrumentation

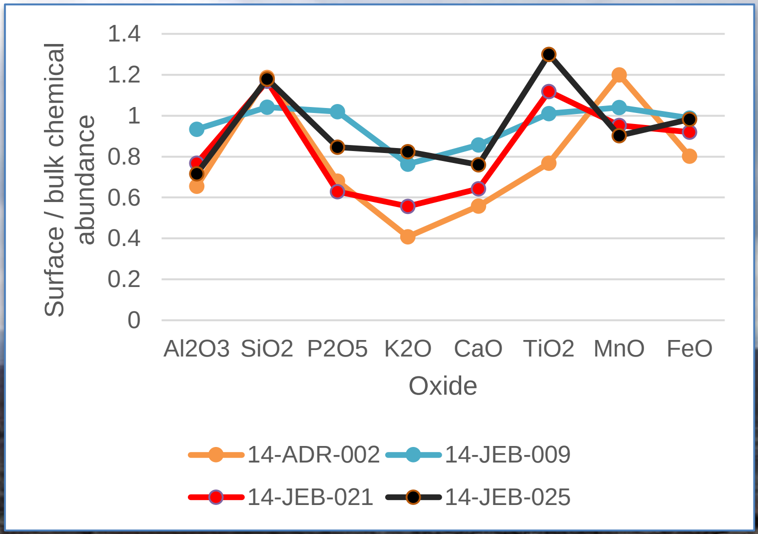
Multispectral Imaging & LiDAR for broad FOV

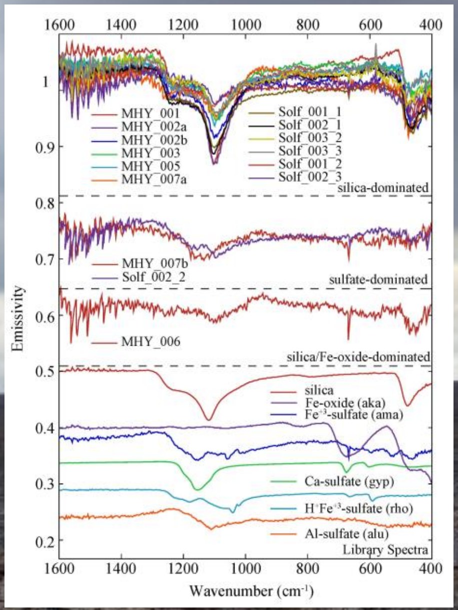
GPR for subsurface structure

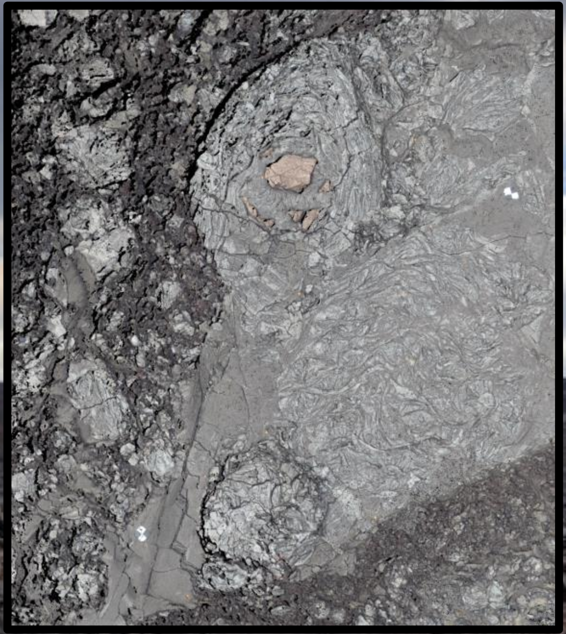
hXRF & XRD for in situ chemistry and mineralogy

Airborne data for site context

The D1974 Flow as an Analog

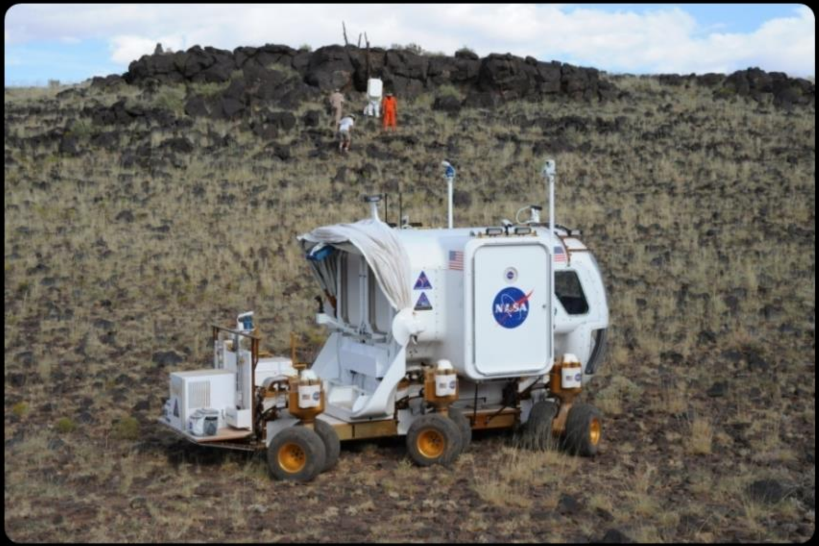






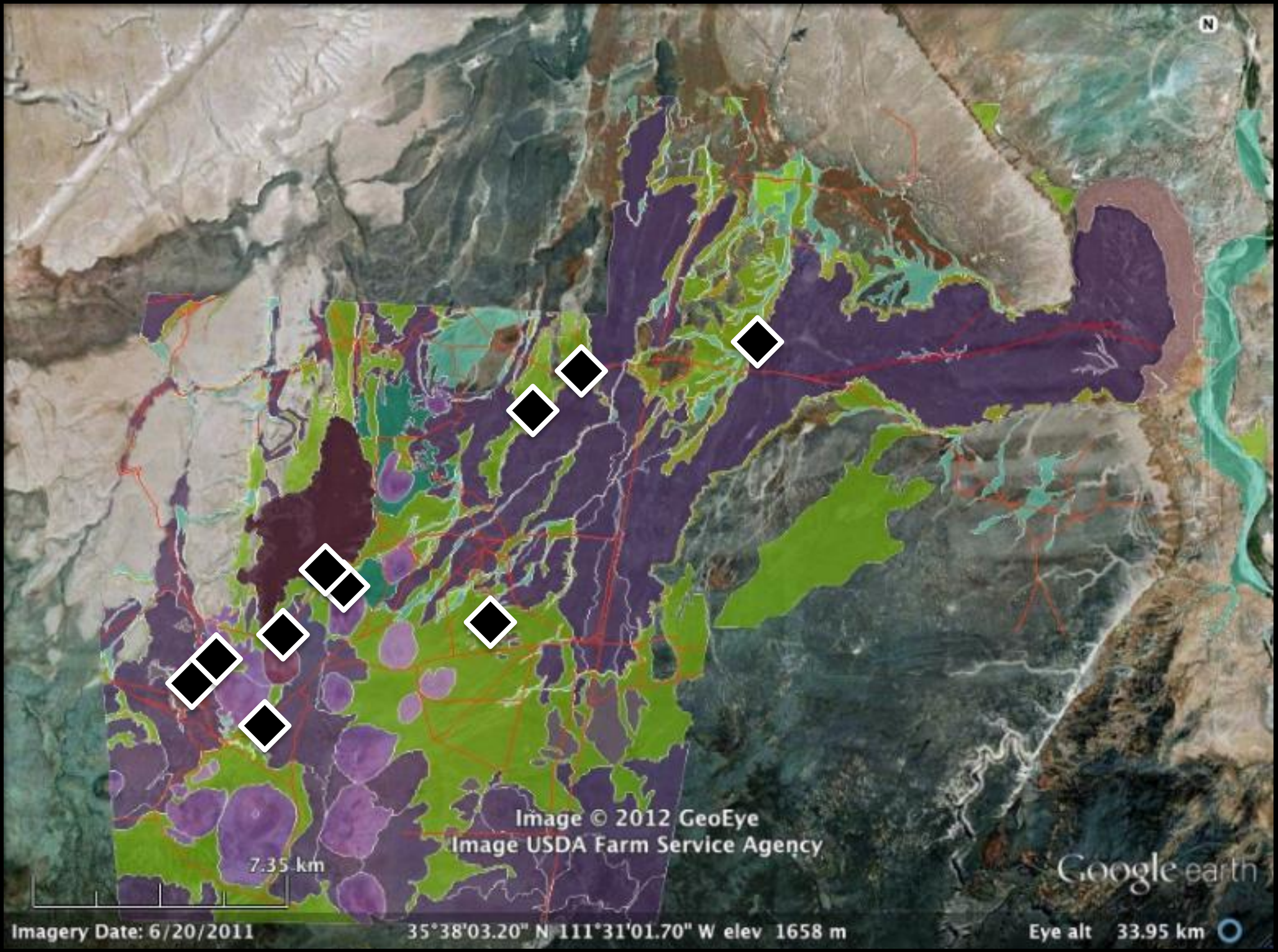
- Alteration Coatings: hXRF, XRD, multispectral imaging
- Solfatara: hXRF, XRD, multispectral imaging
- Flow morphology and emplacement: LiDAR, Kite

Operational Considerations

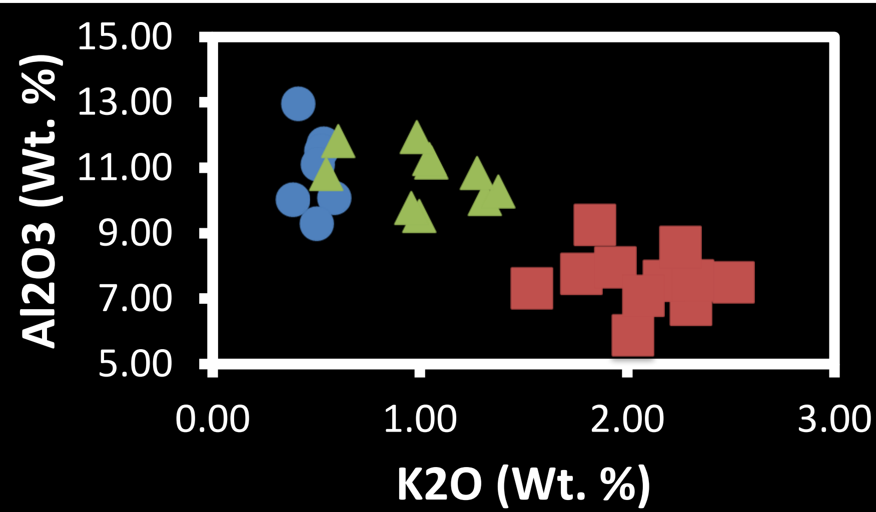


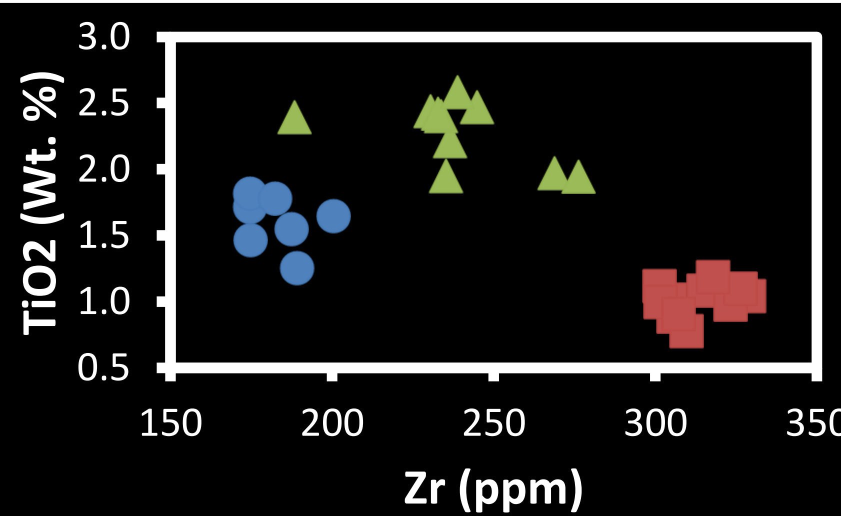
- While increased science value is important, what effect does instrument incorporation have on overall EVA timeline?
- RIS^{4}E builds off of D-RATS heritage to develop operational timelines

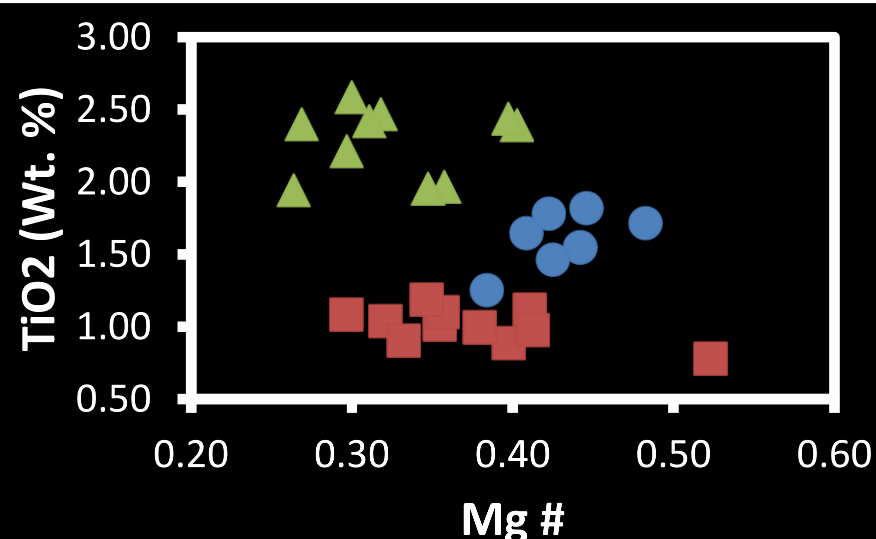
hXRF Case Study



hXRF Data



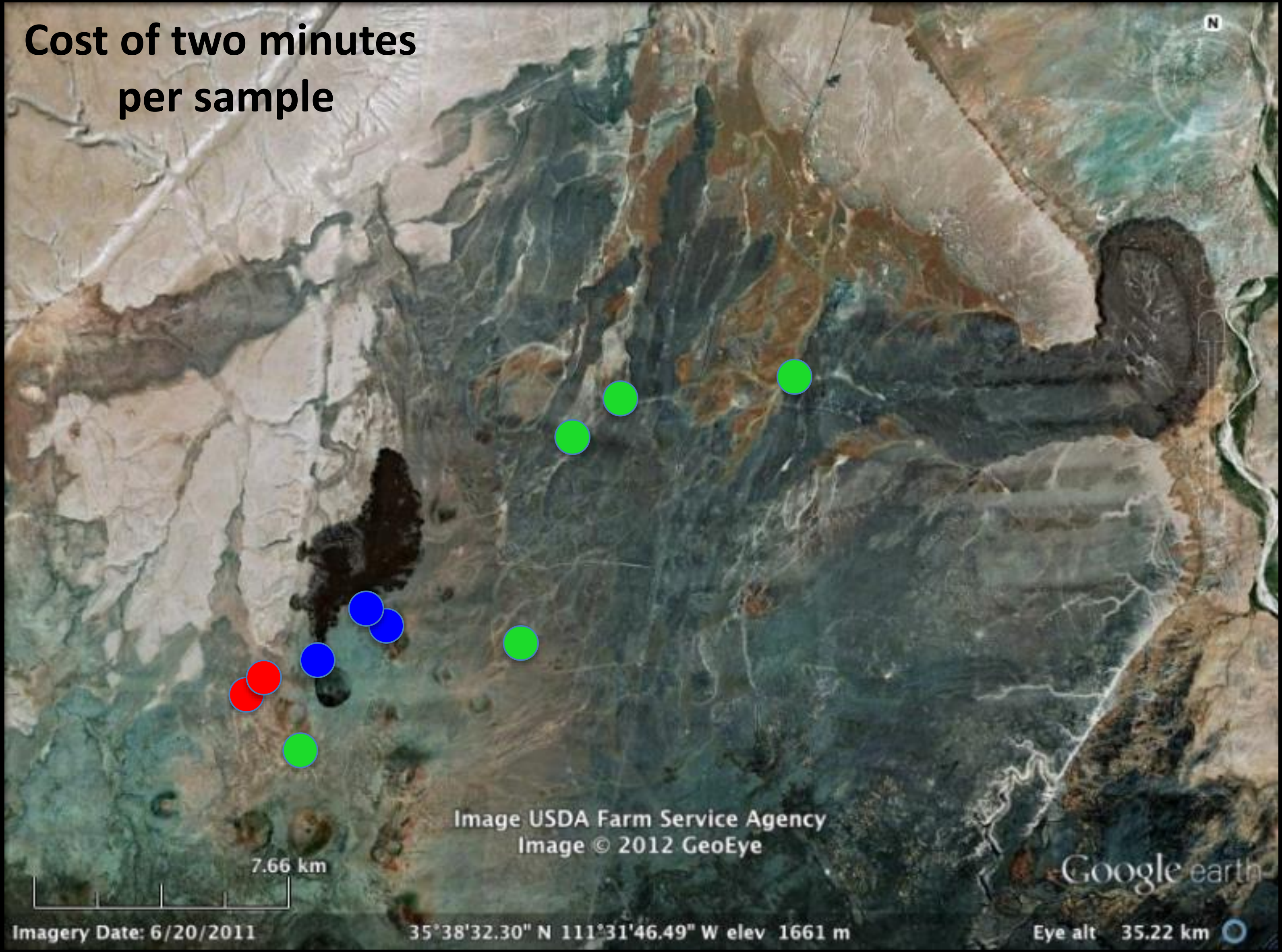




<u>Unit Descriptions</u>

- ■ Unit vf1: low Al, high K, high Zr, low Ti, mid Mg #
- ● Unit vf2: high Al, low K, low Zr, mid Ti, mid Mg #
- ▲ Unknown unit: high Al, low K, mid Zr, high Ti, low Mg #

hXRF Case Study



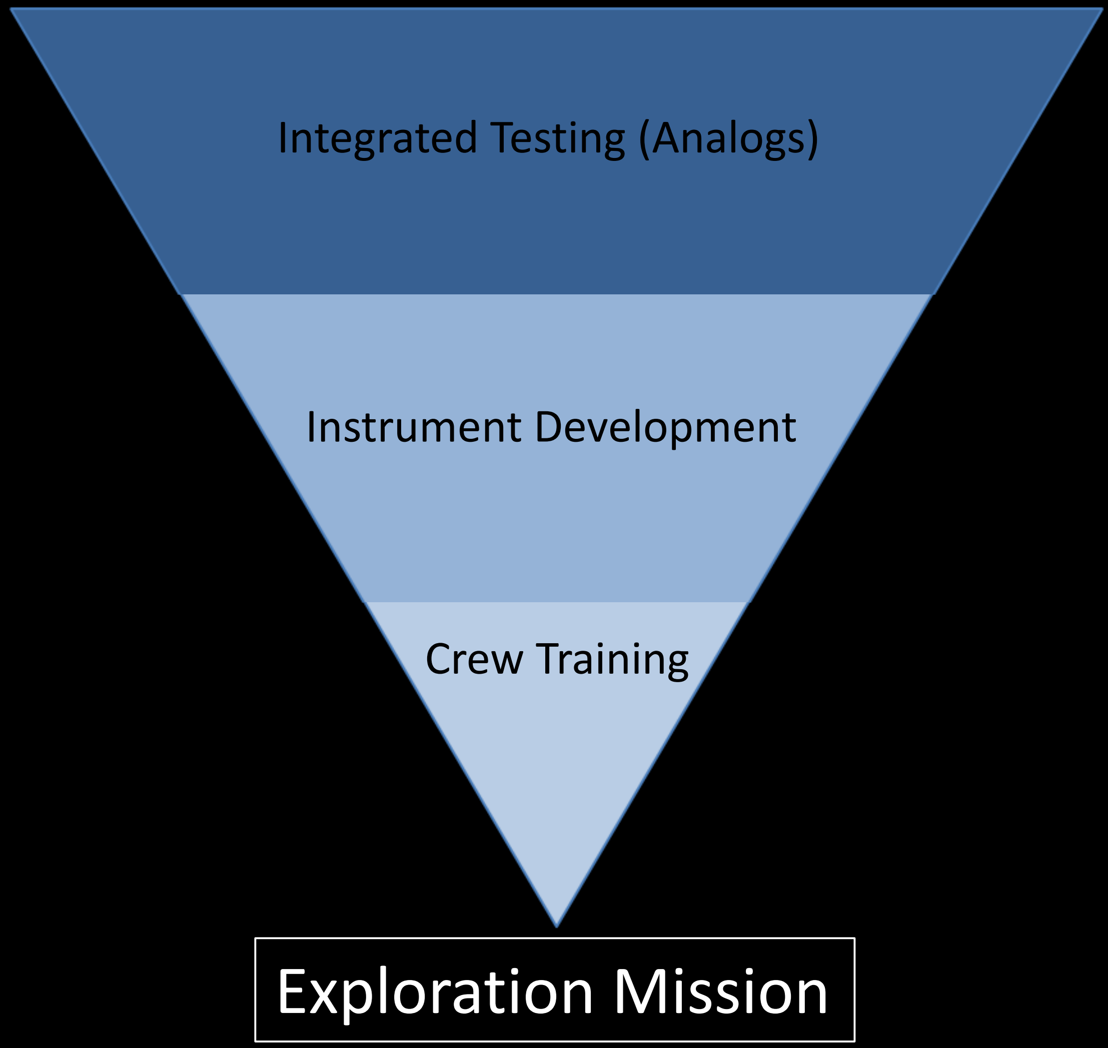
Field Portable Instruments

- Field portable instrumentation is highly beneficial in both sample high grading and gaining real-time contextual insight

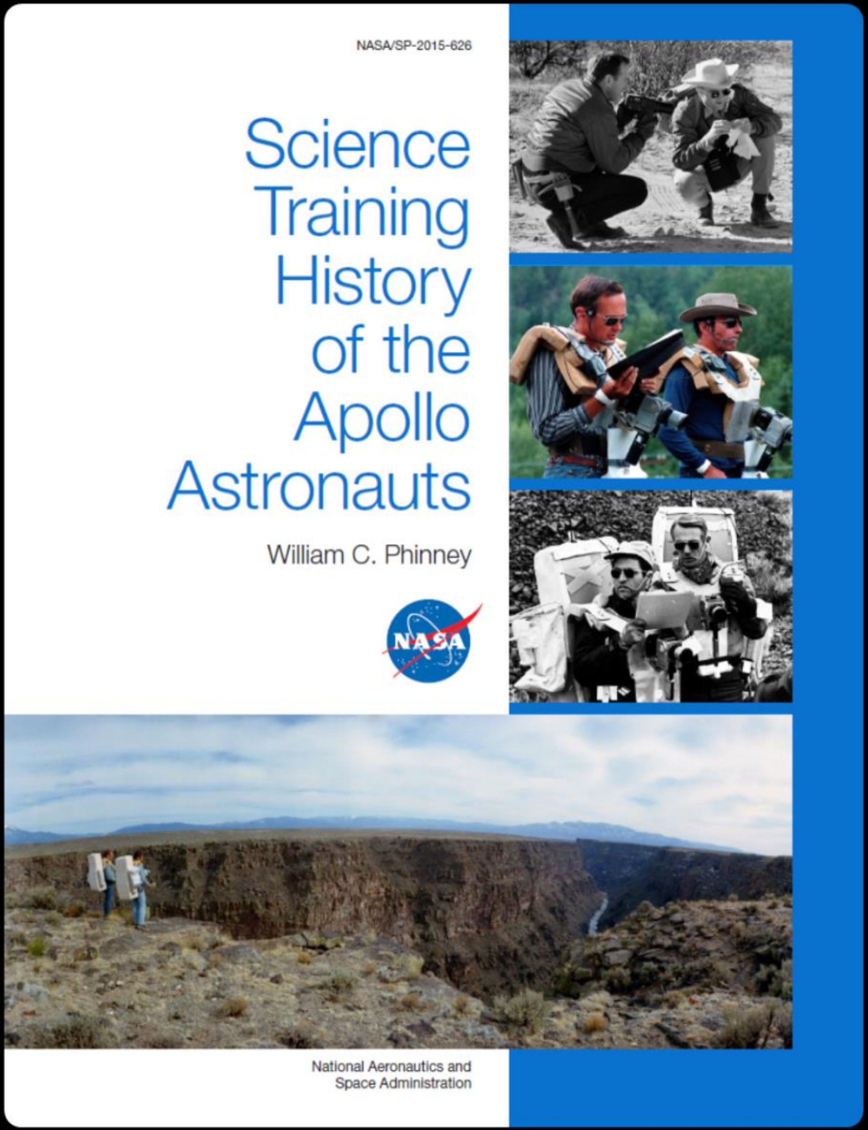
- Selecting an instrumentation suite is non-trivial and should be a priority regardless of target destination

- Work is ongoing to investigate how these instruments will integrate effectively into future planetary EVAs but continued testing in relevant field environments is crucial

Crew Training



Crew Training



Crew Training

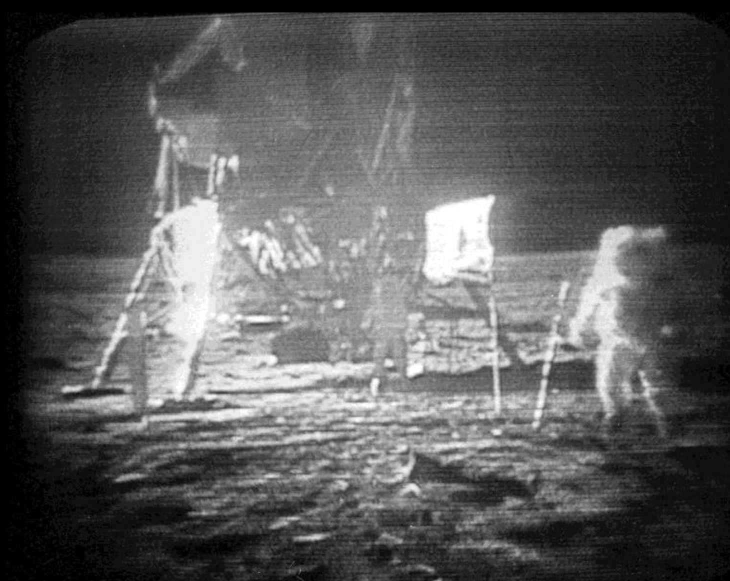
Astronaut Candidate Training

Field Assistant Training

Analog Testing Training

Crew Training

Value of Exploration



Value of Exploration

Cygnus Launch, Oct 17^{th}, 2016

NASA/Bill Ingalls

Launch from H St NE

SpaceX/Dragon

Thank you

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NASA

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